342.123
Labrande

UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE

Project	Date	Author

TITLE

A METHOD FOR PREDICTING THE TREND OF MOUNTAIN PINE BEETLE INFESTATIONS IN WESTERN WHITE PINE

by
W. D. Bedard
Associate Entomologist

&

T. T. Terrell
Scientific Aide

Forest Insect Laboratory
Coeur d'Alene, Idaho
April 3, 1939

SUBJECT—

INDEX NO.—

U. S. GOVERNMENT PRINTING OFFICE 8—9743

File No. [redacted]
Noted by RLF
WJB
JMW

Forest Insect Laboratory
Coeur d'Alene, Idaho
April 5, 1939

Refer to file
Studies B-4A

Dr. F. C. Craighead

Washington, D. C.

Dear Dr. Craighead:

There is enclosed a copy of a laboratory report "A Method for Predicting the Trend of Mountain Pine Beetle Infestations in Western White Pine", by Messrs. Bedard and Terrell. This report describes our first real effort to capitalize upon the data obtained from our study of mountain pine beetle infestations in white pine. We realize full well that this method is based upon what may subsequently prove to be inadequate data. However, we have taken those which are available and are presenting this method as a preliminary step in what we hope will ultimately become an accepted procedure of predicting the trend of mountain pine beetle infestations in white pine. With that reservation we are submitting this report so as to secure all possible criticisms and suggestions for improvements.

A sincere effort has been made to present this subject as clearly as possible, and it is hoped that our readers will not experience too much difficulty in understanding the procedure to be followed. In the mechanical adaptation of this formula, which has been dubbed a robot, some errors will be observed. These errors are purely mechanical and occurred during the process of photographing the original drawings or perhaps are due to our inability to place the holes exactly in the center of each circle. For example, it will be seen that if in the manipulation of this robot the potential brood is set at 10, the attacking brood should be exactly 7.5. However, due to this error it is near 7.7. More substantial copies of these so-called robots will be prepared for field use during the coming season. Obviously, if they are to stand the rigors of field service, it will be necessary to have the circles mounted under some transparent substance.

I assure you that we would appreciate your frank comments and suggestions concerning the substance of this report.

Respectfully yours,

JAMES C. EVENDEN
Senior Entomologist

cc to Mr. Miller, Mr. Keen, Dr. Beal

A METHOD FOR PREDICTING THE TREND OF MOUNTAIN PINE BEETLE INFESTATIONS IN WESTERN WHITE PINE

by
W. D. Bedard
Associate Entomologist

and

T. T. Terrell
Scientific Aide

Forest Insect Laboratory
Coeur d'Alene, Idaho
April 3, 1939

A METHOD FOR PREDICTING THE TREND OF MOUNTAIN PINE BEETLE INFESTATIONS IN WESTERN WHITE PINE

Since the beginning of mountain pine beetle control work in western white pine it has been necessary to select areas needful of control on the basis of number of infested trees per acre. It was realized, however, that owing to the variability in mountain pine beetle abundance, the tendency of an outbreak to increase or decrease would not be shown by the tree per acre figure and that a sounder basis was needed for determining the importance of infested areas. Realizing this need, and for want of something more definite, men charged with these decisions have often used estimates of brood abundance to temper their judgment regarding the need for control in particular areas. In order to secure something more tangible on which to base these decisions, a study of mountain pine beetle infestations in western white pine was started with the primary objective of establishing a biological index whereby the future trend of an infestation could be determined.

A formula for such an index was developed in 1938 on the basis of two seasons' infestation study data and Mr. T. T. Terrell and two of his men tested it for usability during the 1938 survey season. It proved to be practical in application and with some revision it is resubmitted in this report for more thorough testing, particularly as to its accuracy in predicting infestation trends.

In developing the formula two physical factors were given primary consideration, (1) Simplicity, so as to permit its use by any person employed on survey work, and to facilitate sampling so that a large number of samples can be secured in a minimum time, and (2) Sampling to be done at the base of the tree, because time does not allow the felling of all trees to be examined. This necessitates a correction for basal examination because conditions at the base vary somewhat from the tree average.

The formula itself is based on:

(1) The abundance of mountain pine beetle brood per square foot at the base of the tree with corrections for:

(a) basal examination

(b) anticipated mortality

(c) sex ratio

(d) flight mortality

(e) parent adult emergence

(2) Number of attacks per square foot corrected for

(a) basal examination

(3) Amount of infested bark

These factors and corrections have been simplified so that the completed formula is

$$\frac{(B)\ 0.75}{A} \times V = \text{Ratio of increase or decrease}$$

in which B = mountain pine beetle brood corrected for basal examination and anticipated mortality

0.75 = constant correction for sex ratio and flight mortality

A = attacks per square foot corrected for basal examination

V = value given infested bark surface on basis of whether it is average, below, above or well above average.

Development of the Formula

These various factors with their corrections will now be discussed in detail so that their relationship and use in the formula will be apparent. The basis for the basal examination correction is shown in table I, where conditions at the base of the tree are compared with the tree average. In this table the basal examination was taken at five feet and averaged for a 10-foot butt log. The average for the tree includes the basal examination.

TABLE I

Comparison Between Basal Examination and Tree Average

	Basal examination	Tree average	Variation base from tree average: Number	Percent
No. trees sampled	295	295		
Sq. ft. bark surface	12,824	60,744		
No. D. m. brood	21.4	22.0	-0.6	-2.7
No. attacks	6.1	5.5	+0.6	+10.9
No. parasites	2.8	3.6	-0.8	-22.2
No. predators	2.3	1.7	+0.6	+35.3
Sq. in. robber work*	14.8	20.4	-5.6	-27.5

* Robber work comprises wood borer, secondary bark beetle and woodpecker work.

All factors shown in table I are in accord with expectations. Mountain pine beetle bro ds are approximately average, attacks are denser, parasites and robber work are less abundant and predators are more numerous at the base of the tree than throughout the remainder of the bole.

The basis for anticipated mortality corrections is shown in table II, in which both the actual decrease and percentage decrease are shown in the last two columns of the table. The decrease is calculated on the basis of total mortality from any one developmental stage to final emergence so that the actual emergence can be determined for any developmental stage being examined.

TABLE II

D. m. Mortality According to Developmental Stages

Brood stage	Trees examined	Bark surface	Average per square foot	Decrease to final stage	
	no.	sq.ft.	no.	no.	percent
Egg	46	10,030	281.0	266.9	95.0
Tiny larva	57	10,033	142.5	128.4	90.1
Medium larva	42	9,048	51.4	37.3	72.5
Large larva	46	9,039	33.8	19.7	58.2
Pupa	30	5,939	18.6	4.5	24.1
New adult	38	9,475	16.7	2.6	15.3
Emergence	36	8,282	14.1		

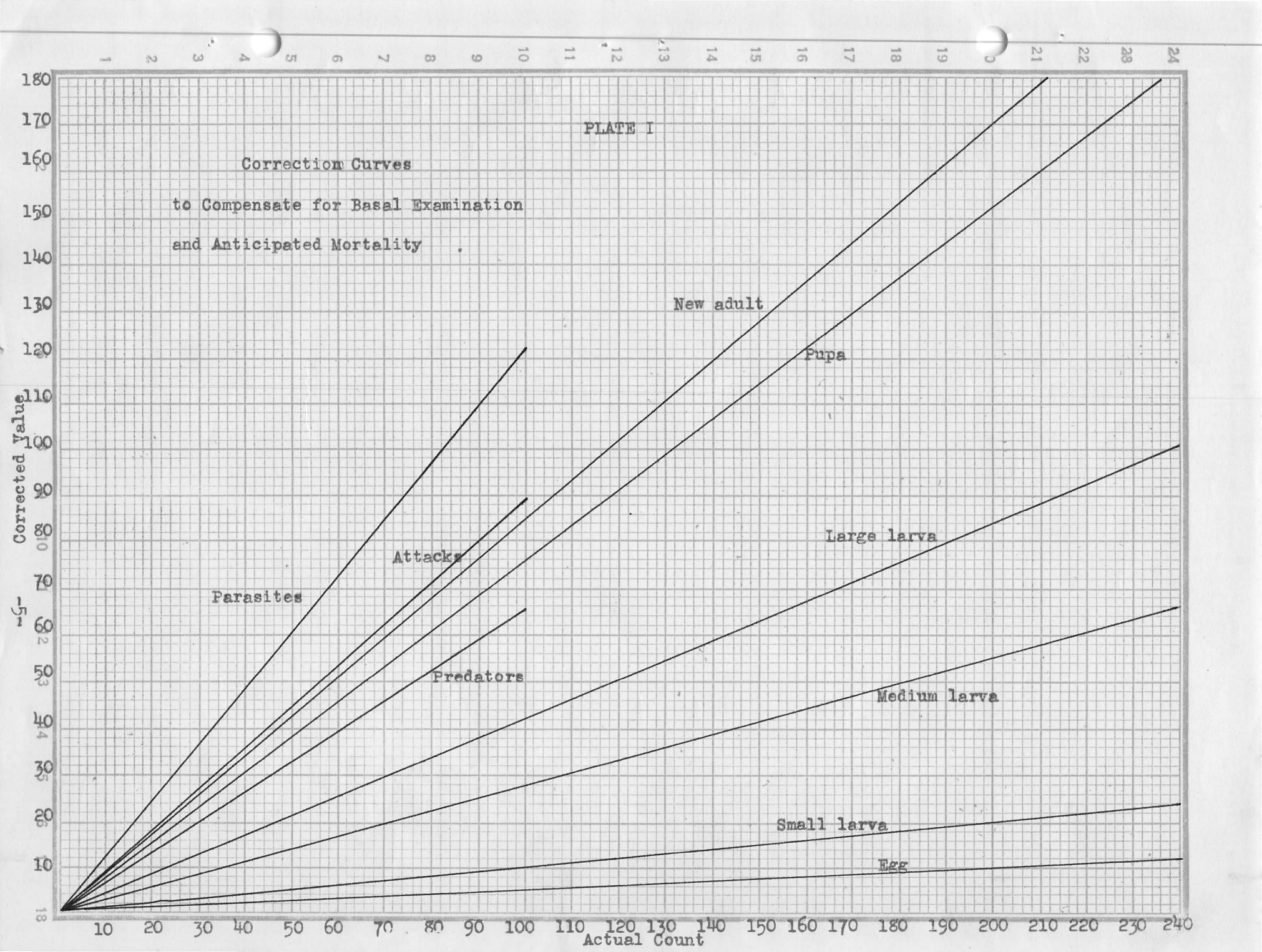
PLATE I
Correction Curves
to Compensate for Basal Examination
and Anticipated Mortality
New adult
Pupa
Large larva
Attacks
Parasites
Predators
Medium larva
Small larva
Egg
Corrected Value
Actual Count
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240

In plate I the corrections shown in tables I and II have been combined to construct correction curves for parasites, predators, mountain pine beetle attacks and all stages in mountain pine beetle development. Thus in plate I corrections for both basal examinations and anticipated mortality have been included in a single curve.

The actual correction for these two factors is accomplished while the examiner is making his counts as will be shown later, and for this reason they have not been included as a part of the formula. The next step then is to ascertain whether the tree under consideration contains sufficient infested bark to be of importance. Infested length in turn depends on bark thickness and total height of the tree. Surprising as it may seem, bark thickness is not closely correlated with tree diameter but for the purpose of this study the average infested length for each diameter class can be considered to be sufficiently close for a determination of infested bark surface. Table III shows the average amount of infested bark for trees in each diameter class.

TABLE III

Average Amount of Infested Bark According to Diameter

D.b.h. inches	Trees examined: no.	Average infested bark sq.ft.	D.b.h. inches	Trees examined: no.	Average infested bark sq.ft.
6-7	6	32	20-21	56	354
8-9	24	63	22-23	43	360
10-11	44	105	24-25	24	410
12-13	85	148	26-27	21	485
14-15	74	175	28-29	6	522
16-17	82	233	30+	9	600
18-19	66	262			

This then provides the basis for determining and correcting the various factors used in the formula. It is true that averages secured in this manner will not be accurate for individual trees, which show maximum variations of ±100 percent in brood, +41 and -36 percent in amount of infested bark, and +33 and -28 in attacks when the robot was tested with actual sampling of 55 trees. These variations are compensating however, as the average of 25 trees shows the error to be ±0 percent for attacks, ±14 percent for brood and ±3 percent for bark surface so that the sampling of 25 trees in any infestation unit will compensate for this variability.

The brood figure which has been secured is the average number of new adult beetles which will emerge from the tree and will have a sex ratio of 0.5, that is, one male for every female. Thus the

brood should be divided by two to secure the actual number of emerging females to compare with the number of attacks. Most of these females will make two attacks, but there will also be some flight mortality so that to secure a fairly accurate figure for the number of attacks the emerging brood will produce, half of the total brood should be multiplied by 1.5. This figure is based on the closest calculation of flight mortality which can be secured from three years' infestation study data. Thus:

$$\frac{\text{Brood (B)}}{2} \times 1.5 = \text{number of attacks (A')}$$

or to simplify,

$$(B)\ 0.75 = A'$$

The next step is to compare the number of attacks which will be made by the emerging brood (A') with the number of attacks in the tree being examined (A), that is, the number of attacks required to produce A'. Thus:

$$\frac{A'}{A} = \text{Ratio of increase or decrease}$$

or the formula thus far:

$$\frac{(B)\ .75}{A} = \text{Ratio of increase or decrease}$$

In order to reduce the data secured to a common basis in relation to the stand, consideration must now be given as to whether the tree being examined has sufficient infested bark to produce enough

beetles to infest an average tree in the stand under consideration. Table III has shown the average infested bark surface for trees of different diameter classes. From this table it is possible to determine whether the infested bark surface of the tree is average, above or below average compared with the adjacent stand. If above average, further determination must be whether it is above average or well above average. For example, in table III if the average tree ranges from 14 to 19 inches, which is typical of most susceptible white pine stands, trees from 6 to 13 inches would be below average, trees from 20 to 25 inches would be above average, and trees over 26 inches would be well above average. Well above average trees although attacked by the mountain pine beetle are rather scarce. These four groups have been reduced on the basis of bark surface to values of 0.4, 1.0, 1.6 and 2.4 to represent below average, average, above average and well above average respectively. Thus, to approximate, below average trees contain half as much bark surface as average trees, above average trees contain half again as much as average trees, and well above average trees contain twice as much. Therefore by multiplying the ratio of increase or decrease determined by the formula thus far by the bark surface value (V) for the tree, the actual ratio of increase or decrease is secured, on the basis of the subsequent season's attacks being in the same density and average or near average trees being attacked. The complete formula would then be:

$$\frac{(B)0.75}{A} \times V = \text{Ratio of increase or decrease}$$

or

Number of average trees infestable

Application of the Formula

The first step which the examiner takes in using the formula is to determine the amount of mountain pine beetle brood and number of attacks per square foot at the base of the tree. Obviously the larger the sample, the better will be the average and it is therefore recommended that at least one square foot of bark be secured for each tree. There are several ways to accomplish this, but from experience best results are secured when a 3-inch by 12-inch vertical strip is removed on each of four sides of the tree.

The actual count of brood and attacks per square foot must be corrected for basal examination, while the brood figure must also be corrected for anticipated mortality in order to determine actual emergence. According to plate I each individual counted may be considered as having the following value: eggs .05, small larvae 0.1, medium larvae 0.27, large larvae 0.42, pupae 0.76, new adults 0.85, attacks 0.89, parasites 1.22, and predators 0.65. Obviously brood counts on this basis would be decidedly confusing to the examiner and it is advisable to simplify the fractions still further. Realizing that the formula is based on averages which may vary from season to season, it is believed legitimate to round out the correction percentages shown in plate I to the extent that they will all be divisible by a common denominator. This would simplify the count, speed up the work and permit a larger, more diversified sample to be secured. Tiny larvae and eggs are always closely associated and are practically the

same as far as mortality is concerned; hence it is believed that these can be considered on the basis of .08 per individual, medium larvae as 0.2, large larvae as 0.4, pupae and new adults as 0.8, parasites as 1.2, predators as 0.6 and attacks as 0.9. This can be further simplified to suit the desires of the individual examiner. For example, in counting mountain pine beetle broods, a common denominator of 8 can be used so that new adults and pupae would be counted as one, large larvae as one-half, medium larvae as one-quarter and eggs and tiny larvae as one-tenth. Then when the count was completed, the sum could be multiplied by 0.8 to return it to its actual value. After having made his count, the examiner now makes use of a mechanical rule or robot developed from the formula by Mr. Terrell.

A rough copy of the robot has been included in the envelope attached to this report to assist the reader in understanding its operation. The device comprises three dials, designated as the "A" or outer dial, the "B" or middle dial and the "C" or smallest inner dial. All of the reading is done on the "A" dial which contains a logarithmic scale copied from the "DF" scale of a polyphase duplex slide rule, but similar to the comparable scale on any slide rule. A logarithmic scale was used so that set points could be used on the "B" and "C" dials to correct for the various factors used in the formula. The "B" dial contains only two points designated as the "potential brood" and the "attacking brood". This dial is used to

correct the examiner's count for parent adult emergence and flight mortality, comparable to the step in the formula of multiplying the examiner's count by 0.75. The "C" dial also contains a logarithmic scale similar to the one on the "A" dial but smaller. This is the attack scale used for dividing the number of attacking brood by the number of attacks as indicated in the formula. The "C" dial also contains four set points indicated as "average minus", "average", "average plus" and "over average plus", which are used to correct for bark surface as indicated in the formula when the quotient resulting from the first part of the formula is multiplied by the bark surface value.

In operating the robot, the examiner first moves dial "B" until the potential brood indicator rests on a number in the "A" scale comparable to the number of pine beetle brood per square foot of bark, which he has determined by actual count. The method of making this count has already corrected it for basal examination and anticipated mortality so that the next step is to multiply his count by 0.75. After the potential brood point on dial "B" has been set on the desired number on dial "A", the attacking brood point on dial "B" indicates the result of this multiplication on dial "A". The next step is to divide this figure by the number of attacks per square foot of bark in the tree under consideration. This is done by selecting the desired number of attacks on dial "C" and moving this dial

until the number of attacks rests opposite the number of attacking brood on dial "A" determined by the previous calculation. The examiner then reads the answer on dial "A" opposite one of the four bark value points depending on the amount of infested bark on the tree being examined. This last step not only performs the desired division but also multiplies by the bark value at the same time, so that the answer secured is the actual ratio of increase on the basis of average trees infestable.

To illustrate the procedure, let us assume a tree actually contains 8 larvae, 10 pupae and 6 new adults per square foot. In making the count with a value of 0.4 for larvae and 0.8 for pupae and new adults, the examiner would have 3.2 larvae, 8.0 pupae, and 4.8 new adults or a total emergence of 16 per square foot. Let us assume that the tree contains 8 attacks per square foot and an average amount of infested bark for the stand under consideration. By setting the "B" dial potential brood arrow at 16 on the "A" dial, the operator reads a value of 12 on the "A" dial opposite the "B" dial attacking brood arrow. This represents the actual number of attacks which will be made by this amount of potential brood. The operator then moves 8 on the "C" dial until it is opposite 12 on the "A" dial, and reads a value of 1.5 on the "A" dial opposite the "average" indicator on the "C" dial. This value represents the ratio of increase on the basis of number of average trees in the stand infestable by the tree just examined.

The operation illustrated arithmetically would be as follows:

Larvae	8 x 0.4	= 3.2
Pupae	10 x 0.8	= 8.0
New adults	6 x 0.8	= 4.8
		16.0 = Total brood

16 brood x 0.75 constant = 12 attacks next year

$$\frac{\text{12 attacks next year}}{\text{8 attacks this year}} = 1.5 \text{ increase}$$

1.5 increase x 1 average bark surface = 1.5 average trees infested next year by one average tree this year.

Care must be used in the placement of the decimal point when using this robot. It is obvious that the value of 1.5 secured in the above calculation could easily become 15, 0.15, etc., unless care is exercised.

Beneficial insects have not been given a numerical value and included in the formula only insofar as they cause the average mortality cared for in the anticipated mortality curves. Obviously when trees containing early developmental stages of the mountain pine beetle are being examined, if parasites are in greater than average numbers, a greater than average mortality will occur, and if in less than average numbers, a lower mortality will result. At this stage of the robot, however, it is believed best to make only an actual count of beneficial insects and record their abundance with the ratio of increase or decrease, so that this figure can be used to temper judgment as to the advisability of control.

Limitations

Obviously any formula to determine the potentiality of an infestation should not include any unpredictable factors such as density of attack, average infested bark surface, or amount of parent adult emergence which is to occur during the following season. These factors are important, however, in determining increases and decreases in the number of infested trees in any area. For example, if the beetles emerge from large, densely attacked, standing trees with long infested lengths, and attack small, unhealthy, weakened trees or windfalls, there will be an apparently rapid increase in the infestation because of less dense attacks and less bark surface per tree, even though the actual bark beetle population remained the same. Conversely, if the infestation emerges from the lightly-attacked material mentioned above and enters large trees, there will be an apparently decided reduction in the infestation.

Therefore it is realized, as previously pointed out, that the "infestation determinator" discussed in this report will not always show the actual increase or decrease in number of infested trees, mainly because of inability to foresee the density of attack and amount of infested bark surface which will characterize the following season's infestation. It will, however, prove entirely satisfactory in predicting the trend of most infestations, particularly

in indicating those so-called "hot spot" infestations the year prior to their "blow-up" or rapid increase. This ability alone will serve one of the greatest needs in mountain pine beetle control in western white pine.

Respectfully submitted,

W. D. Bedard
Associate Entomologist

T. T. Terrell
Scientific Aide